BEYOND LI-ION: WHAT COMES NEXT FOR EV BATTERIES?

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AGENDA

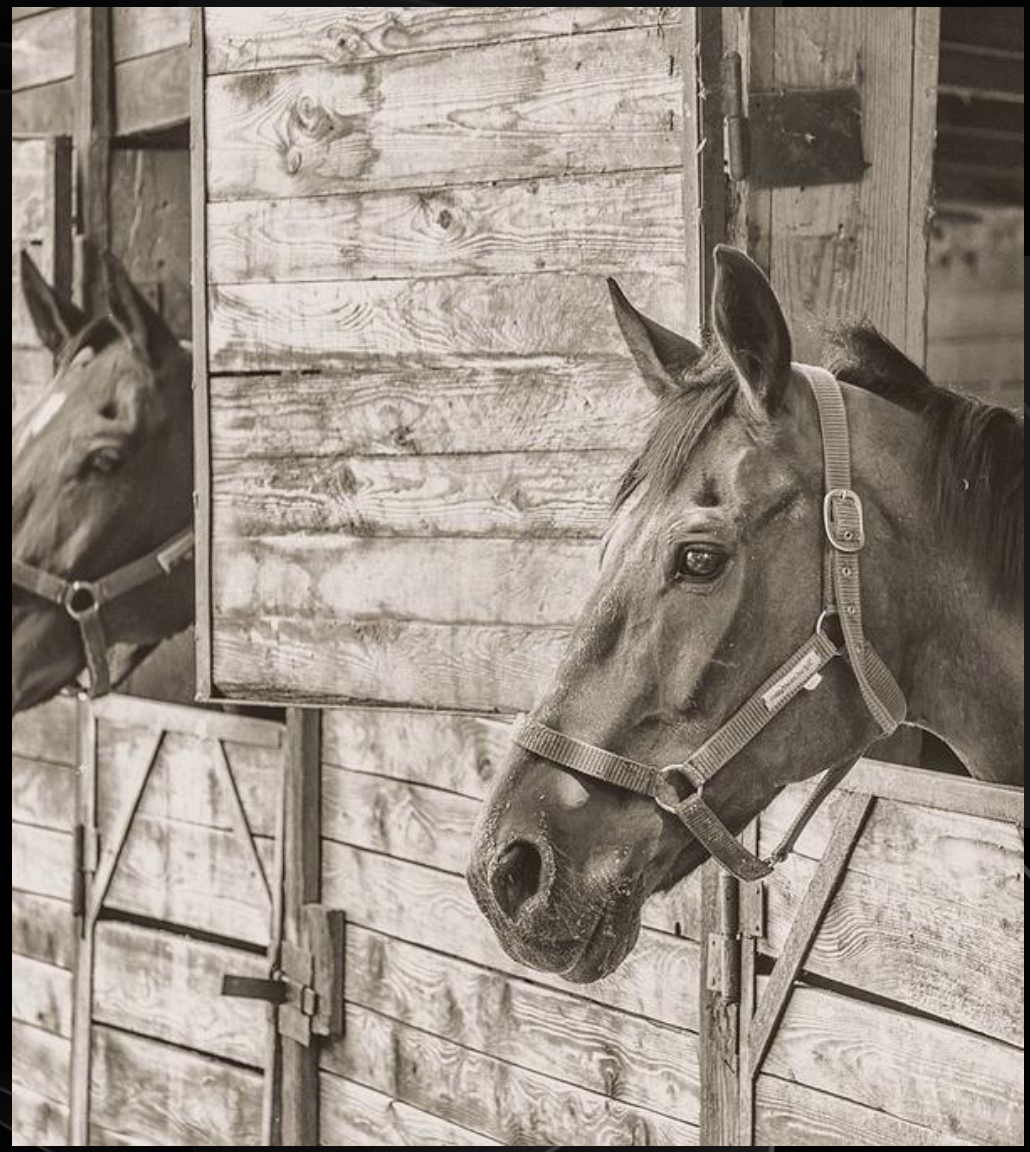
01 **Global battery market today**

02 Consumer perspective and innovations

03 Looking forward

“ ”

In 50 years, every street in London will be buried under 9 feet of manure.



The Great Horse Manure Crisis of 1894

WE DID IT….

New EVs registered

2013 — <250,000 EVs

2022 — 10 million EVs

2023 — >14 million EVs

2024 — >17 million EVs

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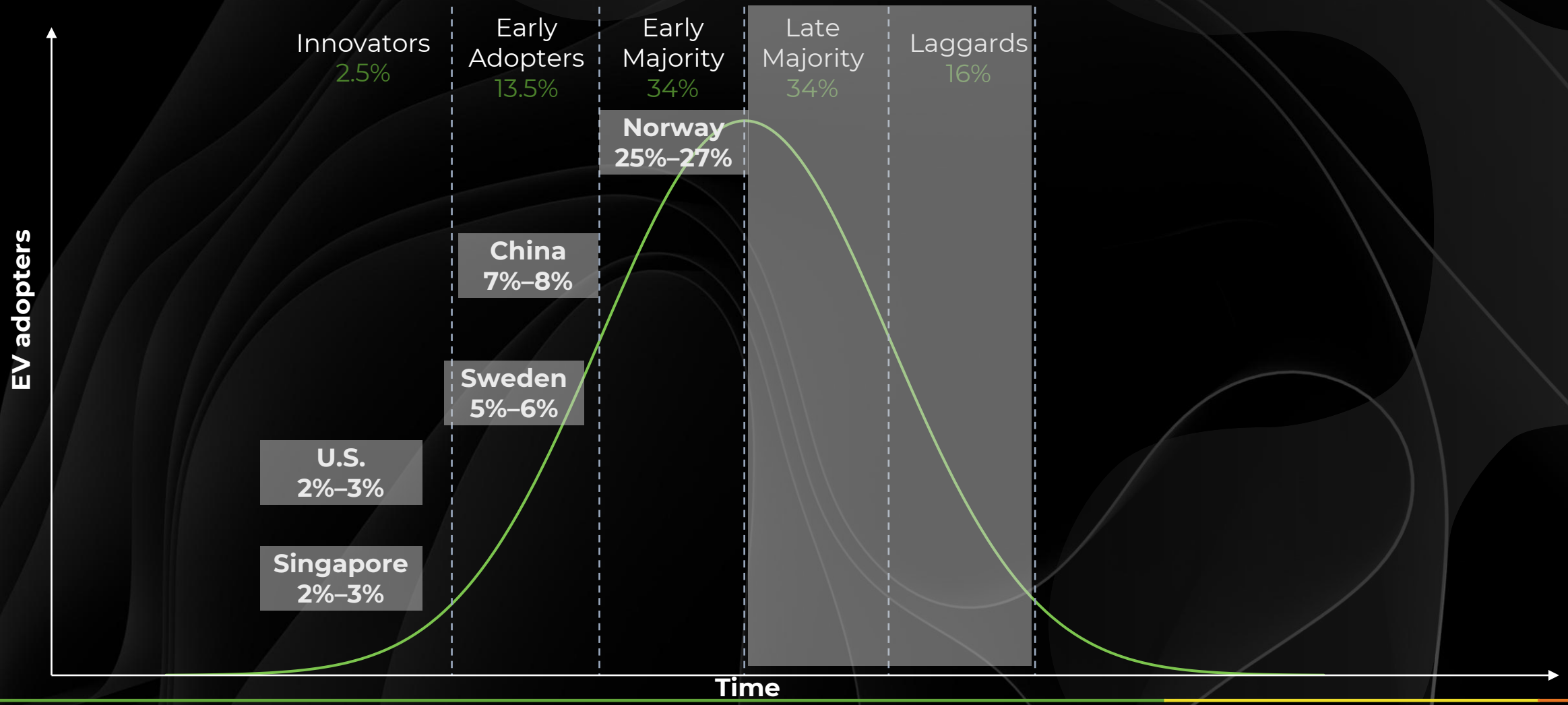
Around 57 million EVs on the road in the world today

UNDERSTANDING THE MARKET



EUROPE'S GIGAWATT DREAMS

Planned – 400 GWh

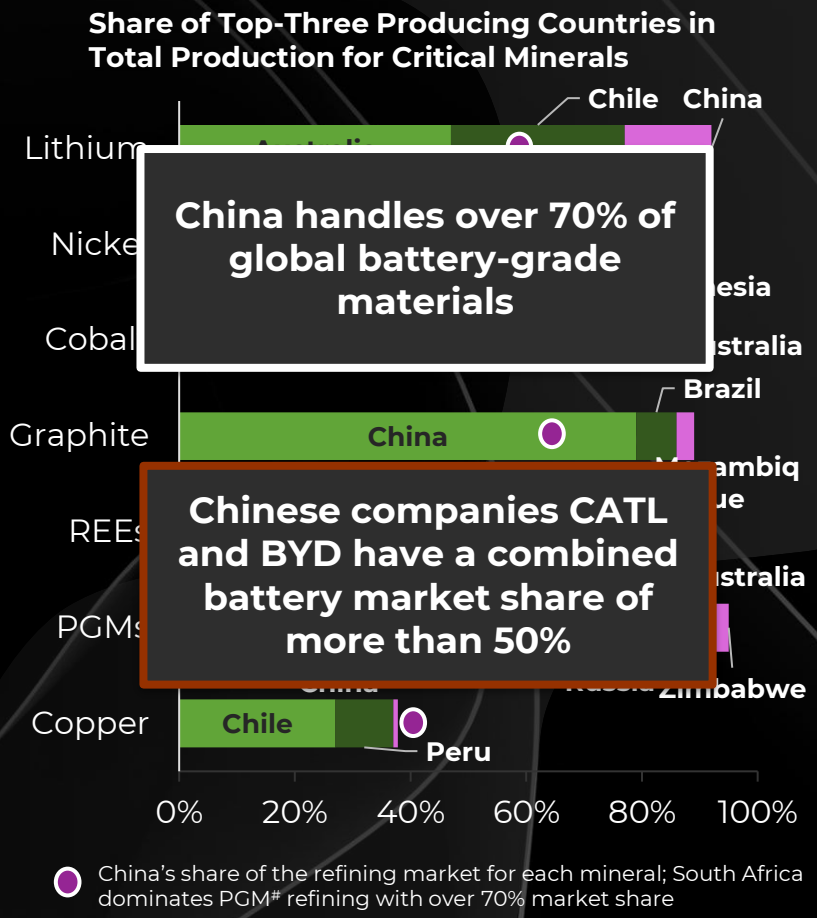
Today, more than 30% of projects have faced hurdles or been canceled

IRA IS IN JEOPARDY

IRA* plans – Over USD 70 billion in funding for battery chemistry and supply chain

Today, grants have been canceled or halted

CHINA IS THE DE FACTO LEADER



*Inflation Reduction Act, #Platinum Group Metals

What are the biggest challenges?

Technology

Production

Consumer

CONSUMER

Slow adoption of EVs is directly related to consumers' ongoing concerns about technology, unreliable information, and inconsistent infrastructure.

- Driving range and charging infrastructure
- Capital and maintenance costs
- Lack of awareness

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JOBS TO BE DONE RESEARCH METHODOLOGY

- **Collect** thousands of **consumer product reviews** around a given topic, focusing on positives and pain points.
- **Analyze conversations and linguistic patterns** to assess participants' deeper motivations and concerns. From these conversations, we **select** the **top-priority jobs.**
- **Assess** how consumers are getting the **jobs done**. What products are they hiring to complete these jobs, and what products are they firing?
- The process allows us to **isolate consumer drivers and make recommendations.**

JOBS TO BE DONE

- Excessive costs associated with owning an EV
- Drive long distances
- Convenient access to charging stations
- Car software enhancing driving experience
- Reliable battery life during cold winter days
- Easy-to-use infotainment system
- Access to frictionless customer service
- Charge EV quickly

I WANT TO AVOID EXCESSIVE COSTS ASSOCIATED WITH OWNING AN EV

Between up-front costs, electric bills, and expensive repairs and maintenance, the true cost of EV ownership is way higher than I want to spend on my car.

Occasions for Maintenance

- **Fixing a minor dent**
- **Charging my EV at home**
- **Getting insurance quotes**

Hiring: EV with minimal features and cheaper parts, insurance plan with an EV discount, home solar systems

Firing: EV with high maintenance costs/expensive parts, insurance plan without an EV discount

Share of Voice

73% of consumers either directly or indirectly connected to this job

I WANT TO DRIVE LONG DISTANCES

I rely on my car to get around, but I fear running out of battery power before reaching my destination and ending up stranded.

Occasions

- **Going on a road trip**
- **Recharging away from home**
- **Driving to work**

Hiring: EVs with long ranges (at least 300-plus miles per charge)

Firing: EVs with a short range, EVs with flimsy/breakable charging ports

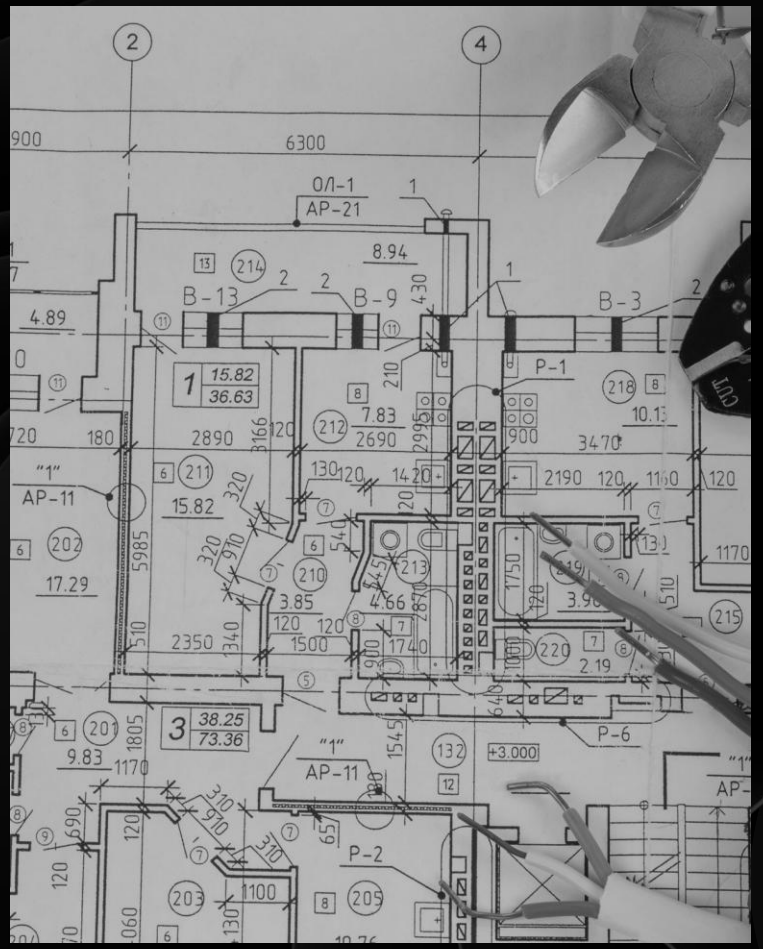
Share of Voice

63% of consumers either directly or indirectly connected to this job

Is there a way to address these?

TWEAKING TODAY'S BATTERIES

BUSINESS MODELS



CHEMISTRY OVERHAUL

TWEAKING TODAY'S BATTERIES

Electrode Innovation

LFP	➢ Safety and thermal stability ➢ Longer cycle life	➢ Lower energy density ➢ Poor performance in cold temperatures
Sulfur cathodes	➢ High energy density ➢ Lower cost of materials	➢ Poor cycle life ➢ Polysulfides affecting conductivity and capacity
Silicon anodes	➢ Higher energy density ➢ Not critical material	➢ Volumetric expansion ➢ Poor cycle life
Lithium-metal anodes	➢ Higher energy density ➢ Higher operating voltage enabled	➢ Thermal runaway due to dendritic growth ➢ Poor cycling stability

TWEAKING TODAY'S BATTERIES

Electrolyte Innovation

Safer liquid electrolytes	➢ Nonflammable ➢ High-temperature stability	➢ Lower conductivity ➢ Expensive
Gas electrolytes	➢ High ionic conductivity ➢ Resistance to thermal runaway	➢ Requires pressure containment ➢ Limited cyclability
Solid-state electrolytes	➢ Higher energy density ➢ Next-gen electrodes enabled	➢ Poor ionic conductivity ➢ High manufacturing costs
Semisolid electrolytes	➢ Higher ionic conductivity ➢ Enhanced safety and mechanical stability	➢ Potential for phase separation ➢ Limited temperature stability

TWEAKING TODAY'S BATTERIES

Electrode Innovation	LFP
	Sulfur cathodes
	Silicon anodes
	Lithium-metal anodes
Electrolyte Innovation	Safer liquid electrolytes
	Gas electrolytes
	Solid-state electrolytes
	Semisolid electrolytes

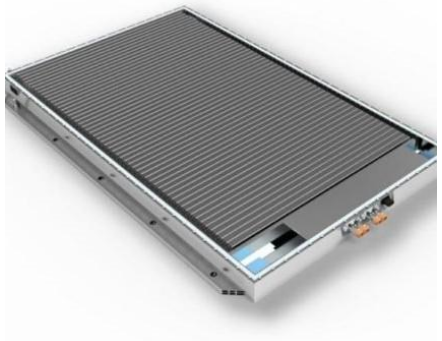
PACK-LEVEL INNOVATION

24M's electrode-to-pack technology comprises a semisolid cathode, an anode, a liquid electrolyte (Eternalyte), and a separator (Impervio) placed between the electrodes.

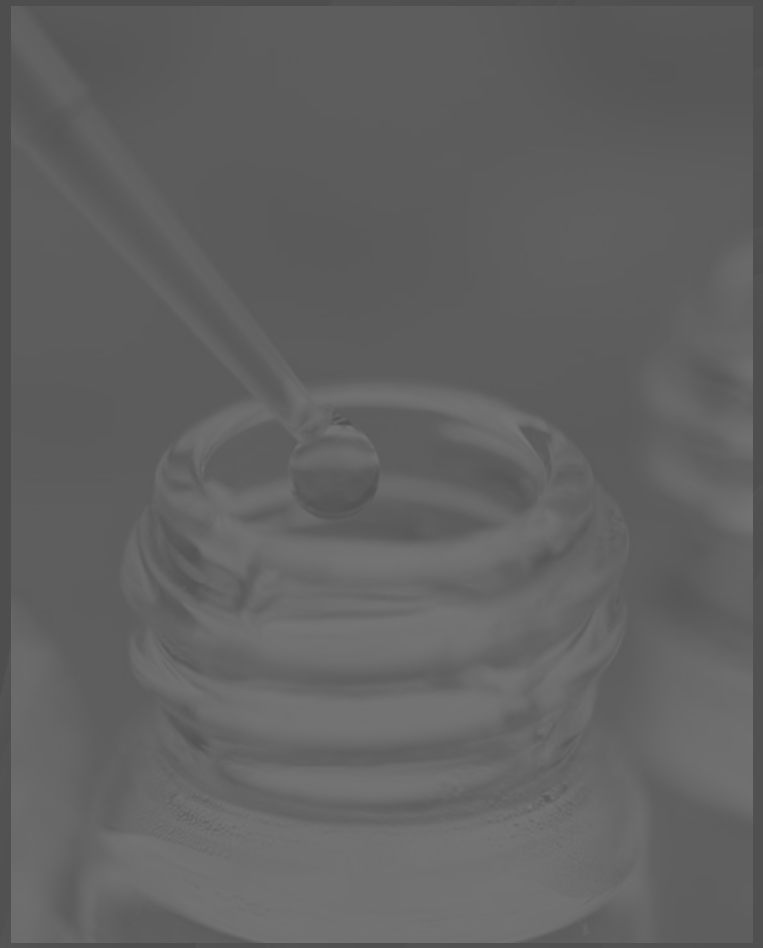
- Li-metal/ NMC ETOP battery yields a specific energy of 350 Wh/kg and more than 500 cycles at 83% capacity retention for 1C discharge/charge.
- It's claimed to eliminate 80% of inactive components and reduce battery costs by 50%.

The Blade Battery is a prismatic LFP battery that features a cell-to-pack design, allowing the cells to be directly integrated into the pack as a structural component.

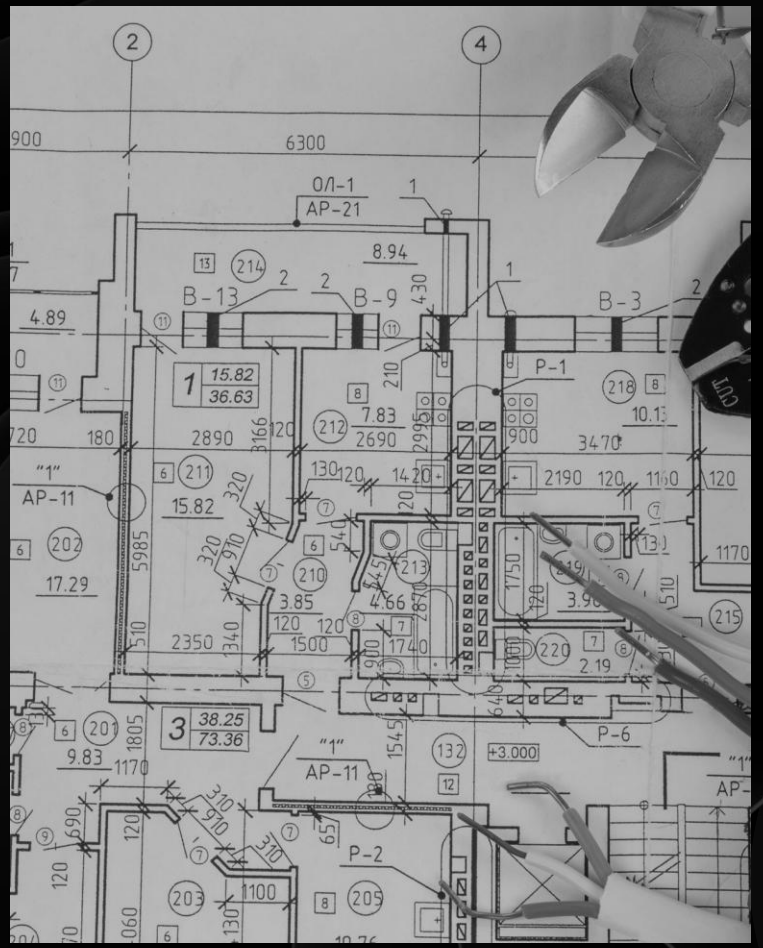
- It eliminates modules, directly integrating bladelike cells into the pack.
- The packing density increases by 50% compared with the current module.



TWEAKING TODAY'S BATTERIES



BUSINESS MODELS



CHEMISTRY OVERHAUL

BATTERY AS A SERVICE

Lease a battery

Customers buy the EV without the battery and pay a monthly fee for battery usage.

- Charging models include a subscription-based monthly fee or a variable rate based on the distance traveled in kilometers.
- It reduces the EV upfront costs by 30% to 40%.

Image source: Bing

BATTERY SWAPPING

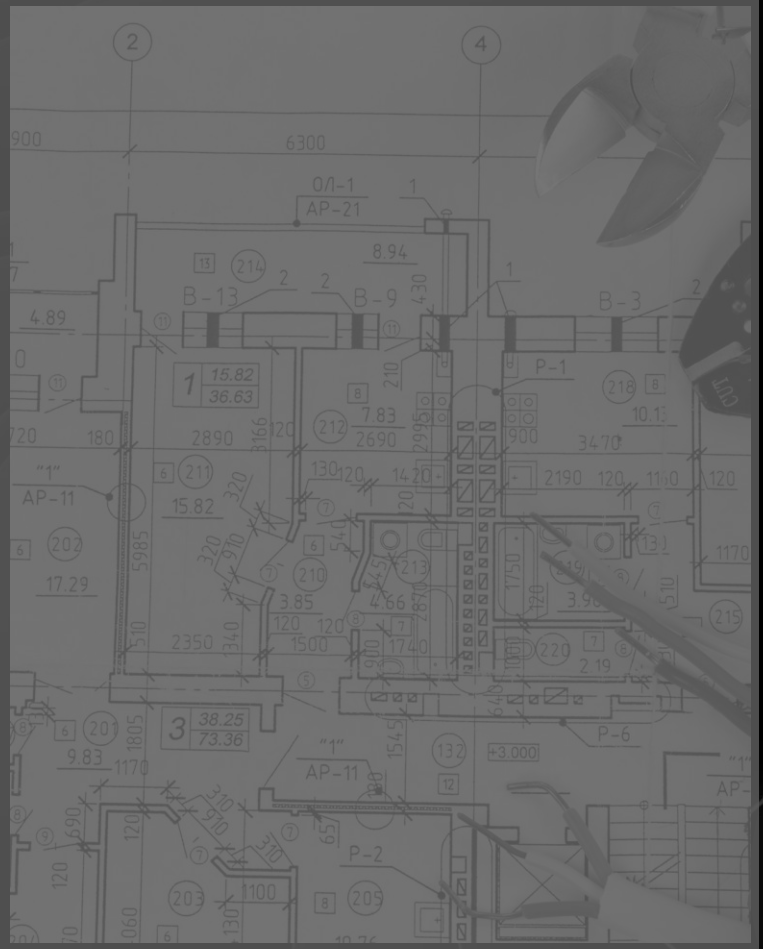
A combined solution for grid stability and fast-charging needs

Battery swapping offers the cycle life benefits of slow-charging batteries but faster range addition than even the fastest charging stations.

- A swap can be completed under five minutes.
- It slows the degradation of the batteries.
- Swappable packs need to be standardized, which presents a barrier to adoption.

TWEAKING TODAY'S BATTERIES

BUSINESS MODELS



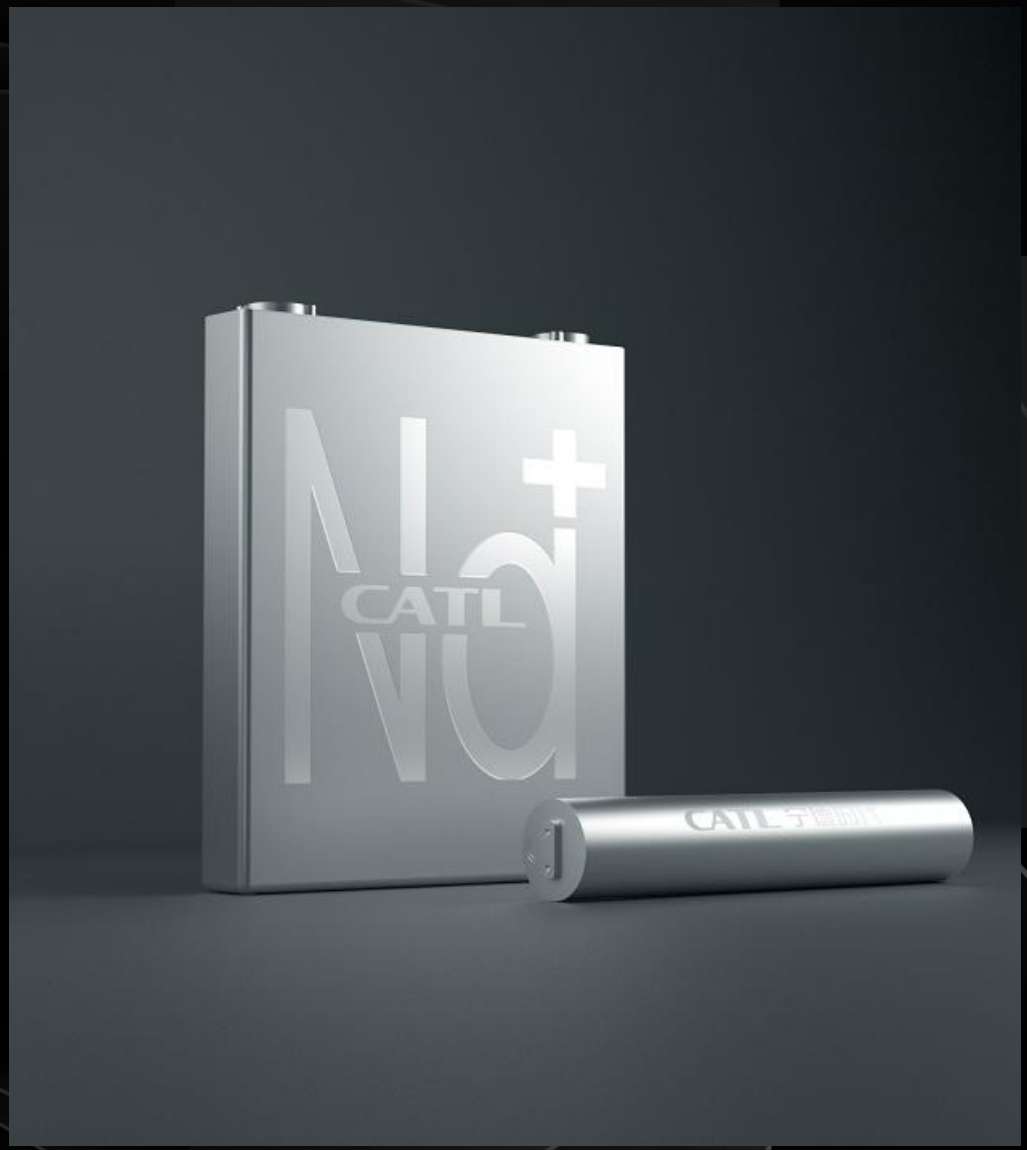
CHEMISTRY OVERHAUL

CHANGING THE LANDSCAPE OF LOW- AND MIDRANGE CARS

CATL – AB Battery

CATL's AB battery pack has found the right balance between introducing Na-ion without succumbing to its drawbacks and achieving lower costs through a multipurpose Li-ion manufacturing facility.

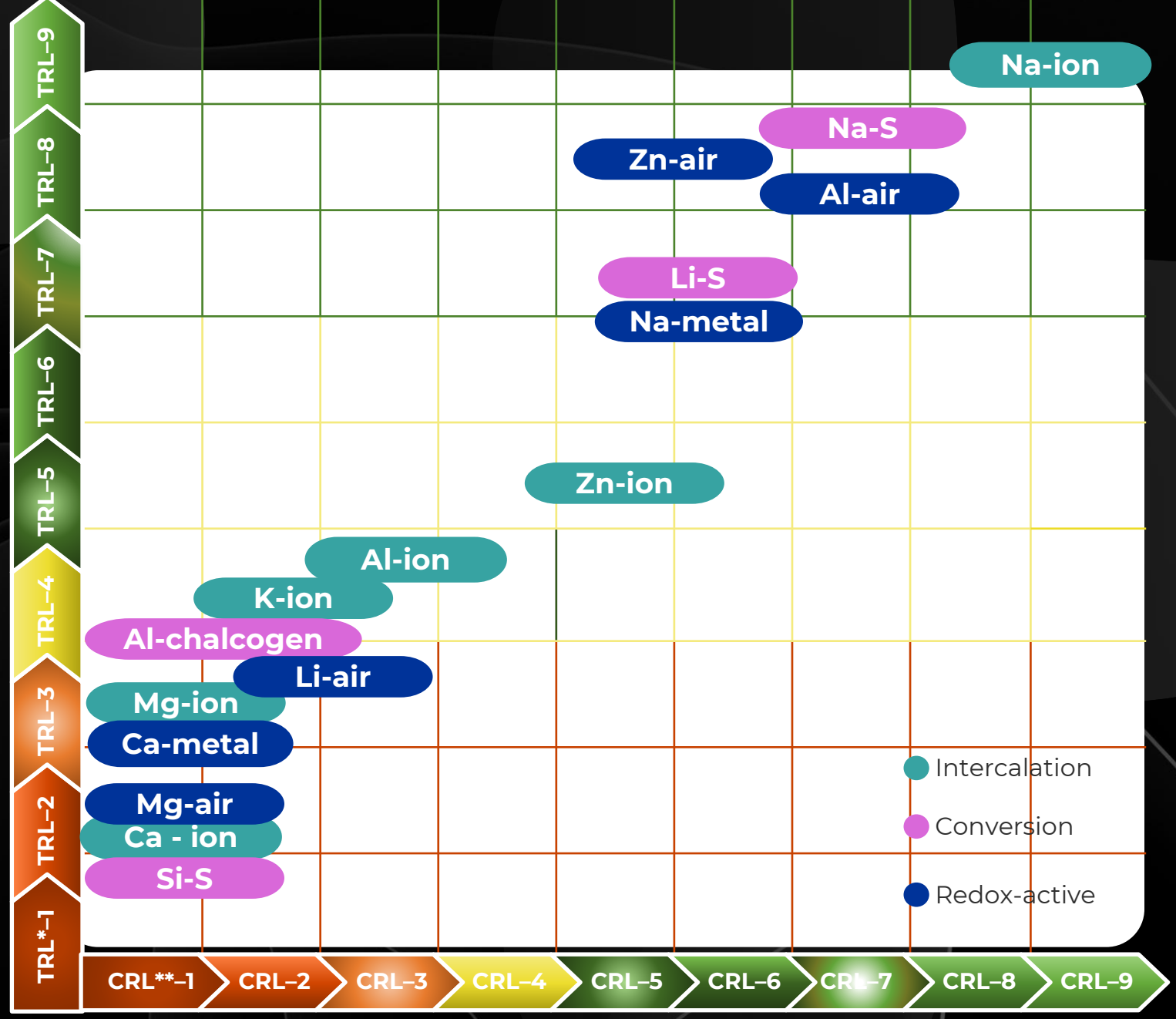
- The pack comprises Na-ion cells with Prussian blue cathode and graphite/NMC* Li-ion cells.
- The price target is USD 40/kWh, with an expected range of 250 km per charge.



*Nickel manganese cobalt

BEYOND LI-ION CHEMISTRIES

The technical requirements of stationary storage and electric mobility and the lack of consolidated efforts in a single novel battery technology will keep the space fragmented and unable to surpass Li-ion demand.



*TRL, technology readiness level; **CRL, commercial readiness level

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WILL THERE BE A COMPLETE OVERHAUL?

The answer is **NO**.

Li-ion batteries are here to stay!

2025–2030

- Commercialization of battery technologies aiming to optimize energy density while ensuring a robust supply chain for raw materials, all rooted in the foundational principles of Li-ion technology
- Innovation in battery pack design, electrode integration, and charging infrastructure

2030–2040

- Efficient manufacturing technologies, usage of recycled or locally sourced materials, and adoption of chemistries as per applications and affordability
- Adoption of technologies other than Li-ion in niche and further concentration of managing life cycle of Li-ion batteries

BEYOND 2040

- Adoption of beyond Li-ion technologies on the wider scale
- Emergence of fuels beyond batteries

INNOVATION AND CONSUMER PRIORITY

	Cost Concerns	Range Anxiety	Charging Infrastructure Network	Software Glitches	Intuitive Infotainment System	Battery Life in Cold Climates	Efficient Charging	Poor Customer Service
EV battery swapping	3	4	2	1	1	5	5	1
Autonomous vehicles	1	4	2	5	3	1	1	3
Dynamic wireless charging	1	5	4	1	1	2	3	1
Generative AI	1	1	4	5	5	1	1	3
DC fast-charging infrastructure	1	4	3	1	1	2	4	1
Novel battery chemistries	4	2	1	1	1	3	1	1
Advanced sensors	1	2	1	2	2	2	2	3
Li-ion batteries	3	2	1	1	1	1	1	1
OTA software update	1	1	1	4	3	2	1	1
Consumer wearables	1	1	1	4	3	1	2	1
3D printing	2	1	1	1	1	1	1	5
Bidirectional charging	3	1	1	1	1	1	1	1
Software-defined vehicles	1	1	1	2	3	1	1	3
Thermal management materials	1	1	1	1	1	3	3	1
AR/VR	1	1	1	2	3	1	1	1
Critical minerals extraction	2	1	1	1	1	1	1	1
Novel photovoltaics	1	2	1	1	1	1	1	1
Microgrids	1	1	2	1	1	1	1	1
Advanced coatings	1	1	1	1	2	1	1	1
Biobased materials and chemicals	1	1	1	1	1	1	1	1

KEY TAKEAWAYS

1

Transformative business models aim to enhance the adoption of EVs.

- Implementing battery swapping and leasing options for batteries could motivate customers to consider EVs.
- Diagnostic tools for the secondary use of batteries are a must to establish EVs' reliability and transparency.

2

The vulnerability of the supply chain needs tactical resolution.

- Rather than bypassing China, slow phasing out will be a more economical solution.
- A closed-loop supply chain and vertical integration among stakeholders in the value chain are needed to stabilize production.

3

Geographically viable non-Li-ion solutions will gain momentum.

- Commercialization of alternative chemistries will be application-based.
- Policies and regulations to locally source materials will solely depend on the country's strength and citizen needs.

THANK YOU

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